



National Defence
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DREA Contractor Report 98/450

TRANSCAL

USER'S MANUAL (VOLUME II)

by

Ron Cunningham

PERNIX TECHNOLOGY

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Dartmouth, Nova Scotia, Canada

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CONTRACTOR REPORT

Prepared for

**Defence
Research
Establishment
Atlantic**



**Centre de
Recherches pour la
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Atlantique**

Canada

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Abstract

This report is part of a two volume set. It describes the work done in a research contract to develop transducer calibration software, referred to as TRANSCAL, for use in the Defence Research Establishment Atlantic (DREA) calibration facilities. This volume describes the procedures for directional response measurements and reciprocity measurements. The first volume (CR/97/414) contains a description of the procedures for the transmitting voltage response and receiving response using swept sine, pulse or CW. The TRANSCAL software controls the calibration procedure, acquires and processes the received data, and presents the results. The system has been developed using the LabVIEW programming environment, to operate on a Macintosh Quadra 900.

Résumé

Ce rapport fait partie d'une série de deux volumes. Il décrit le travail fait sous contrat pour développer le logiciel d'étalonnage de transducteur, nommé TRANSCAL, à être utilisé dans les facilités d'étalonnage du Centre de Recherche - Atlantique. Le présent volume décrit les procédés à suivre pour mesurer la directivité et la réciprocité. Le premier volume (CR/97/414) contient la description des procédés à suivre pour mesurer la sensibilité et la sensibilité de réception en utilisant la fréquence de balayage d'une sinusoïdale, une impulsion ou une onde continue. Le logiciel TRANSCAL contrôle le procédé d'étalonnage, acquiert et traite les données reçues, et présente le résultat. Le système a été développé en utilisant l'environnement de programmation LabVIEW pour un Macintosh Quadra 900.

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Introduction

This introduction presents an overview of the capabilities and features of TRANSCAL. The organization and use of this manual are described and notational conventions explained.

About TRANSCAL

In the generation and acquisition of underwater acoustic signals, various transducers may be used to provide the interface between the physical pressure fluctuations and the electrical analog of these fluctuations. These transducers include devices which function as sound projectors, hydrophones (underwater microphones), or both. Calibration of the transducers is required to enable the correct interpretation of a received signal, or to ensure the desired result in the case of a projected signal.

Calibration of hydrophones involves the measurement of the receiving response, the admittance and the directional response patterns. The measurement of the receiving response of a hydrophone is the measurement of its free-field voltage sensitivity by comparison to the sensitivity of a known standard hydrophone. Electrical admittance is the measure of the electrical ratio current/voltage.

Calibration of projectors involves the measurement of the transmitting voltage response or the transmitting current response, the admittance or the impedance and the directional response patterns. The transmitting voltage (or current) response is the ratio of the sound pressure apparent at a distance of one meter in a specified direction from the effective acoustic center of the transducer to the voltage applied across (or the current flowing into) the electrical input terminals. Electrical impedance is the measure of the ratio voltage/current.

DREA has two facilities for transducer calibrations: the DREA Barge — Acoustic Calibration Facility on Bedford Basin and the DREA anechoic tank. Using these facilities, several calibration procedures are possible:

- (1) Transmitting response using swept sine, pulse or CW.
- (2) Receiving response using swept sine, pulse or CW.
- (3) Directional response.
- (4) Receiving response using pseudo-random noise.
- (5) Reciprocity.
- (6) Receiving response for an array using swept sine, pulse or CW.
- (7) Admittance measurement.
- (8) Impedance measurement.

The TRANSCAL software controls the calibration procedure, acquires and processes the received data and presents the results. The current version of TRANSCAL implements all of the functions above except item (4) and (6). This volume describes the directional response function and the reciprocity function. The other functions have been described in the first volume (DREA CR/97/414).

Special features

TRANSCAL includes these features:

- A flexible data acquisition environment, including user-selectable pulse width and sampling delay.
- The ability to hold at any frequency, modify settings and observe results, then proceed.
- The ability to switch between pulse and CW modes on-the-fly.
- A variety of dataset presentation options for each procedure, including transmitting voltage response (TVR), transmitting current response (TIR), admittance, and impedance.
- User-defined frequency range.
- Autogain of acquired signals, with a dynamic range of 150 dB.
- Plotting of formatted results directly from within TRANSCAL.

System requirements

To use TRANSCAL, you need the following hardware and software:

- A Macintosh Quadra 900 computer with 20 MBytes RAM and 200 MBytes disk space.
- National Instruments NuBus boards NB-A2000, NB-DMA-2800, and NB-TIO-10.
- Printer.
- Real Time Systems Programmable Amplifier Model RTS 3510B.
- Wavetek Brickwall Filter Model 753A.
- Wavetek 50 MHz Synthesized Arbitrary Waveform Generator Model 296.
- Instruments Inc. Voltage and Current Sensor Model VIT-13.
- Power amplifier.
- Macintosh® system software version 7.0 or later.
- National Instruments LabVIEW® software version 3.1 or later.
- TRANSCAL software.

About this manual

This manual contains instructions for configuring and operating the TRANSCAL software. This section describes the scope and organization of this manual, and the conventions and nomenclature used in developing it.

This manual is intended for the technicians and technologists who are responsible for installing and operating the TRANSCAL system. You should be familiar with Macintosh® computer operations and general underwater acoustic research concepts. However, it is not necessary to be an acoustics signal acquisition and processing expert; Part 1 of this guide provides conceptual information you will need to use TRANSCAL.

Before using TRANSCAL, you should know how to use the mouse and locate files using directory dialog boxes. If you are unfamiliar with the Macintosh user interface or need more detailed information regarding these procedures, please refer to your Macintosh user's guide.

Organization of this manual

The TRANSCAL user manual comprises two volumes. Volume 1 covers data acquisition basics, and hardware and software installation. It also contains the user manuals for Transmit Response mode, Receive Response mode, and Admittance and Impedance measurements using the transmit response mode. This volume, Volume 2, describes the Directional Response and Reciprocity calibration modes.

Conventions used in this manual

The following conventions are used in this guide:

Terms that appear in *italic* type are defined in the paragraph in which they appear. The glossary also defines other terms that are related to your use of the TRANSCAL software.

◆ **Note** Text set off in this manner presents sidelights or interesting points of information. ◆

△ **Important** Text set off in this manner—with the word *Important*—presents important information or instructions. △

Associated documents

You might also find it useful to refer to *LabVIEW for Macintosh User Manual* for a complete description of the LabVIEW software package.

Part 2

Procedures

8 Using Directional Response Mode

Starting Directivity

You activate the directivity response calibration procedure from the *TRANSCAL* main panel. The front panel will startup as shown in Figure 8-1.

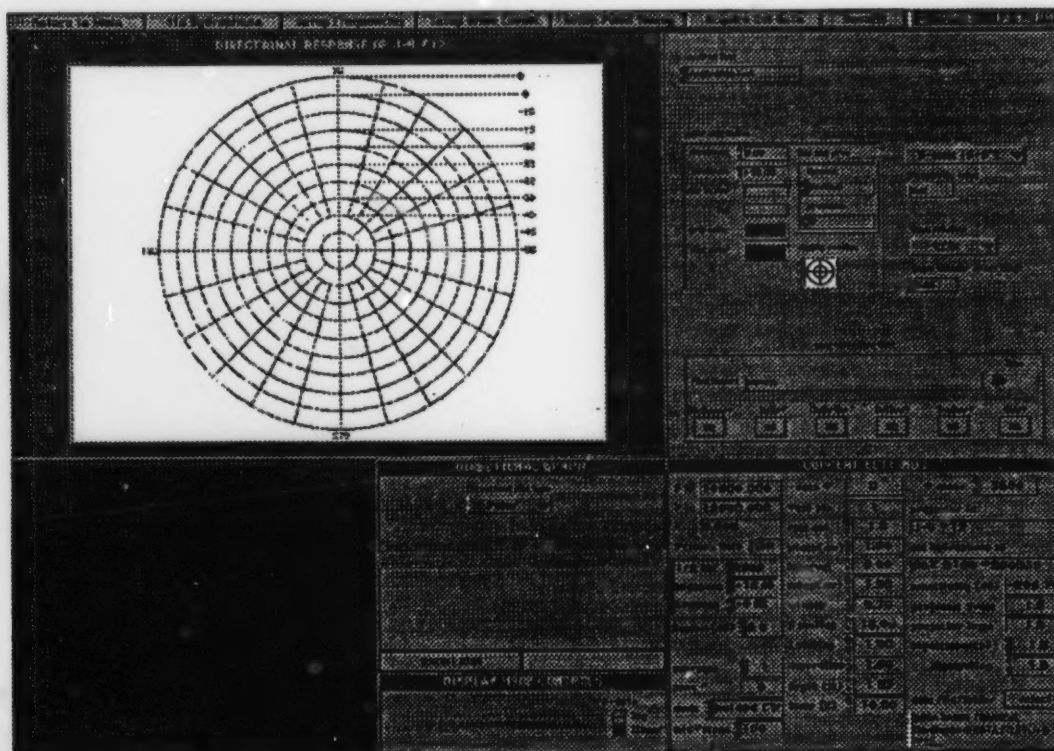


Figure 8-1 Directivity Response front panel

Directivity Response Calibration step-by-step

This section will present a simple guide to the basic operations of directivity response calibration. All required parameters have default values, so it is possible to execute a calibration simply by pressing the *Acquire Cal Data* button. Typically it will be necessary to change some values or settings for the actual experiment.

Step 1: Startup

Startup as described above. During startup, the standard hydrophone selection panel will appear. Press *Done* to accept the standard shown, or select a new one as described in the *Selecting the standard hydrophone calibration* section.

Step 2: Check the CURRENT SETTINGS

Check that the CURRENT SETTINGS are appropriate for your calibration experiment. The settings which may require changing are:

System Gains

Account for any system gain blocks not included in the preamp or filter gains. Typical examples would be the 6 dB preamp high-impedance gain or an attenuator added to cut down signal levels. Set this using the *System(dB)* control.

Number of Averages

If more than one pass is going to be averaged, set this using the *averages* control.

Excitation Mode

Usually, pulsed sine tones are used, but if CW is required, set it using the *mode* control.

Minimum scans

The program will calculate the correct number of scans, based on your pulse parameter selections. If you wish to look at a longer signal, set the minimum number of scans in the *min#scans* control.

Output Signal Level

The default output level is 1 volt rms. If this is too large, enter the required level using the *rms out* control.

Source Pulse Width

The minimum duration of the source pulse is set using the *width(ms)* control. The value entered will be a minimum length. The actual length will depend on the pulse frequency, partial cycles are not generated.

Sampling Delay

In water, there is a delay while the pulse travels from the projector to the hydrophone. The length of the delay, in milliseconds, is specified in the *delay(ms)* control so the system knows where to begin looking for received data.

Sampling Window

The *window* control is used to set the width, in milliseconds, of the time window from which the system will extract samples for calculations. If you wish to see the effects of changes to the pulse parameter settings, use the *Setup Pulse Timing* button.

Projector Scaling

The actual projector voltage is typically much larger than the available measurement range. The front panel of the projector voltage and current monitor has controls to select gain factors for voltage and current measurements. These scaling factors must be reported to TRANSCAL, using the *V scaling* and *I scaling* controls. If the selected gain is 100mV/V, for example, the scaling factor is 10.

Transducer Depth

Enter the actual depth in meters using the *depth (m)* control.

Temperature

Enter the water temperature in degrees Celsius using the *temp (C)* control.

Step 3 Check the frequency range

The current frequency settings are reported in the *F hi* and *F lo* indicators. If new settings are required, use the *Setup Frequencies* button to change the values, as described in a later section.

Step 4 Run the calibration

Before beginning a calibration run, the rotation station has to be positioned. If the station shaft encoder readout panel has just been powered on, the station must be rotated past the zero-degree point. This will allow the encoder interface to lock on to the zero pulse. Position the station 10 or more degrees in advance of the zero position. Set the rotation direction control on the Directivity front panel to match that of the rotation station drive control panel.

To initiate the calibration run, press the *Acquire Cal Data* button on the front panel. Immediately start the station rotation by turning the speed control knob. Typical settings are 25 in the Tank, and 18 on the Barge. Exact speed setting is not critical – too slow and the run will take too long; too fast and the system might miss pulses. You can abort the run using the *ABORT RUN* button. When the run has been completed, the graph will be updated with the calibration results.

Step 5 Print the results

Use the *Results* button to get printed plots, or to save the calibration data to a file.

Controls and indicators

Modal Controls

The controls shown in Figure 8-2 redirect control to other front panels, or cease operation. This section briefly describes the function of the controls. The sections detailing the purpose and operation of the resulting front panels follows later in this chapter.

Return to Main	Std Hydrophone	Setup Frequencies	
Setup Drive Levels	Setup Pulse Timing	Acquire Cal Data	Results

Figure 8-2 Modal controls

Return to Main

This button returns control to the TRANSCAL main panel, from which other calibration procedures can be accessed, or the session can be ended.

Std Hydrophone

This button redirects control to the *Standard Hydrophone Sensitivity* panel, used to select the calibration curve for the standard hydrophone to be used in the projector calibration.

Setup Frequencies

This button is used to redirect control to the *Setup Frequencies* front panel, used to set the calibration frequency range.

Setup Drive Levels

This button is used to redirect control to the *Setup Drive Levels* front panel, used to set the projector drive levels.

Setup Pulse Timing

This button is used to redirect control to the *Setup Pulse Timing* front panel, used to set the pulse generation and sampling parameters.

Acquire Cal Data

This button starts the calibration process.

Results

This button is used to plot calibration curves or save the calibration data to a file.

Directional Response graph

The *Directional Response* polar graph (Figure 8-3) displays the Directional Response of the test transducer. Response is displayed, as a function of frequency, in units of decibels relative to the maximum response. Alternately, the data may be displayed in cartesian form, shown in Figure 8-4.

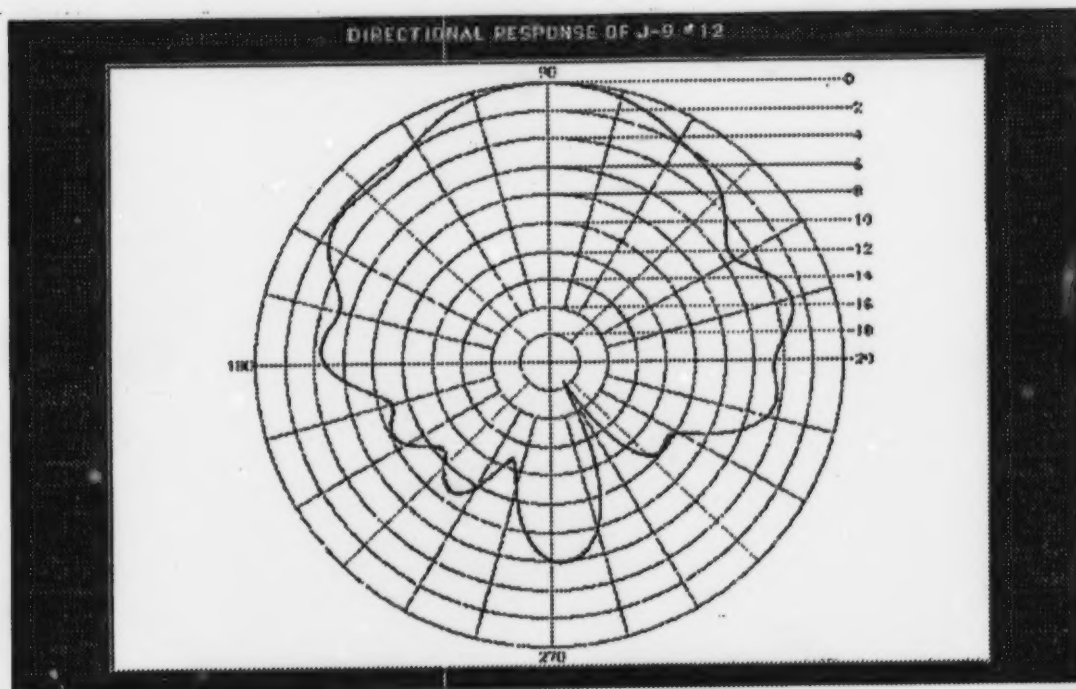


Figure 8-3 Directional Response polar graph

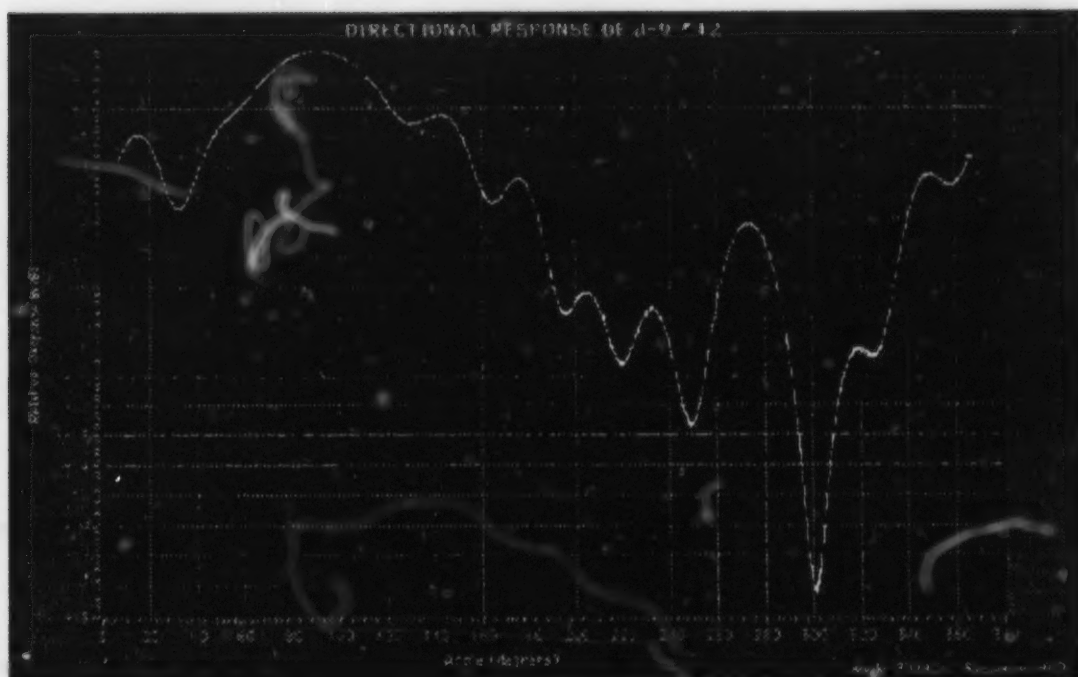


Figure 8-4 Directional Response cartesian graph

Directional graph control

The graph type displayed in the directional response graph is selected by pressing on the directional plot type selection button, dragging the cursor to the desired selection, and releasing the mouse button. The appearance of the control during the selection is shown in Figure 8-5.



Figure 8-5 Directional graph control

Display Mode Controls

The only active display mode control in Directivity mode is the X-axis log or linear control. This control is seen in Figure 8-6.



Figure 8-6 Display Mode Controls

Calibration run controls

The calibration run controls (Figure 8-7) are used to pause or abort the calibration process. The *HOLD FREQUENCY* button is disabled for Directional response mode. The *ABORT RUN* button stops the current scan.

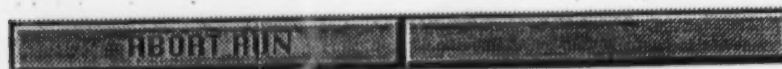


Figure 8-7 Calibration run controls

Current Settings

Current Settings, shown in Figure 8-8, is a collection of controls and indicators which provide an interactive reporting of the current process status.

CURRENT SETTINGS			
F hi	10000.000	scan	0
F lo	10000.000	*cal pts	1
F	0.000	rms out	1.0
Preampl Gain	30	width (ms)	1.00
1/2 BW	2000	interval	0.00
Highpass	+10 dB	delay (ms)	1.50
Lowpass	+0 dB	window	0.70
System (dB)	6.0	V scaling	10.00
averages	1	I scaling	1.00
pass	0	separation	1.00
mode	pulsed CW	depth (m)	1.83
min *scans	100	temp (C)	10.00
		projector id	J-9 #12
		std hydrophone id	B&K 8100 #806539
		sensitivity (dB)	-206.79
		projector Vrms	1.8
		projector Irms	1.8
		capacitance (nF)	1.8
		dissipation	1.8
		data file/folder	select
DREA BARGE TRANSCAL Development: DATA FILES: J-9 #12			

Figure 8-8 Current Settings controls and indicators

F hi

This indicator shows the maximum frequency setting for the calibration run.

F lo

This indicator shows the minimum frequency setting for the calibration run.

F

This indicator shows the current frequency setting during the calibration run.

Preamplifier Gain

This control shows the current gain setting for the RTS 3510B programmable amplifier. The control is used to enter the gain to be used for the calibration. Autogain is disabled.

1/2 BW

This control determines the bandpass of the brickwall filter. You enter the filter half-bandwidth, which is the frequency separation between the current centre frequency and the lowpass and highpass cutoff frequencies. That is, the total bandwidth is twice the entered value.

Highpass

This indicator shows the current highpass gain setting for the brickwall filter. You select the desired value from the available settings for the filter. Autogain is disabled for directivity mode.

Lowpass

This indicator shows the current lowpass gain setting for the brickwall filter. You select the desired value from the available settings for the filter. Autogain is disabled for directivity mode.

System (dB)

This control is used to enter any other gain blocks which are present in the system. For example, if an attenuator is required, its gain value would be entered here.

◆ **Note** The system gain control is configured to default to 6 dB (to account for the RTS 3510B gain offset when output into a high-impedance load). ◆

Averages

This control is used to enter the number of passes which get averaged to calculate the final calibration curve.

pass #

This indicator shows the current pass number, providing feedback on the progress of the calibration.

mode

This control is used to select the signal source mode, that is pulsed sine or continuous waveform (CW). The mode can be changed at any time, even during a calibration pass.

min # scans

During data acquisition, the system calculates the number of minimum number of scans required to capture the specified pulse. You may want to acquire additional data, say to look at reverberation effects. This control is used to set the minimum number of scans acquired. The actual duration of acquired data gets displayed as the X-axis of the graphs, and will depend on the current sampling frequency. For example, 750 scans at a 250 kHz sampling rate would result in 3 milliseconds of data.

scan #

This indicator displays the current scan in progress.

cal pts

This indicator displays the total scans required to complete the data acquisition.

rms out

This control is used to enter the source signal output level. The control is set to limit the maximum output level to 1.0 volts rms, a standard value for amplifier calibration.

width (ms)

This control sets the source signal pulse width for pulsed operation. The value, in milliseconds, represents a minimum pulse width. An integral number of waveform cycles will always be generated, so the actual pulse width is typically longer than the specified value.

interval

This control is used to specify a minimum interval, in milliseconds, between the end of one excitation pulse and the beginning of the next. Under normal circumstances, the next pulse is generated once the calculations have been completed for the previous pulse. This control should be left at zero for maximum system speed.

delay (ms)

This control is used to enter the delay from the start of the excitation pulse to the beginning of sampling of the hydrophone voltage. Typically, it would be set to the travel time for the pulse from the projector to the hydrophone, plus some time to allow the initial transients to decay.

window

This control is used to enter the allowable time window, in milliseconds, for sampling the hydrophone voltage waveform. The program will attempt to maximize the amount of data acquired to improve the result. A maximum number of integral half-cycles will be sampled from within the specified window. The time window begins at the end of the specified delay, and continues for the value specified in this control.

V scaling

This control is used to enter the voltage scaling factor manually selected on the front panel of the VIT-13 amplifier voltage and current monitor. For example, if the voltage setting is 100mV/V, then the scaling factor is 10.

I scaling

This control is used to enter the current scaling factor manually selected on the front panel of the VIT-13 amplifier voltage and current monitor. For example, if the current setting is 1 V/A, then the scaling factor is 1.

separation

This control is used to enter the separation, in meters, between the projector and the hydrophone.

depth (m)

This control is used to enter the depth, in meters, between the surface and the hydrophone.

temp (C)

This control is used to enter the water temperature, in degrees Celsius. This value is used to annotate the data plots, and is stored to file with the calibration data.

projector id

This control is used to enter the Identifier string for the projector.

std hydrophone id

This control is used to enter the identifier string for the hydrophone. The identifier is saved in the stored data files.

sensitivity (dB)

This indicator shows the standard hydrophone sensitivity at the current test frequency.

projector Vrms

This indicator shows the applied projector voltage, in rms volts, at the current frequency.

projector Irms

This indicator shows the applied projector current, in rms amperes, at the current frequency.

capacitance (nF)

This control is used to enter the measured capacitance, in nanoFarads, of the hydrophone and cable combination under test. This value is recorded in the data file.

data file/folder

This indicator shows the current folder and filename to which saved data will be stored. The filename prefix forms the root of the filename. A date and time tag is appended to this prefix to create a unique filename for each file. You change the folder and filename by pressing the select button and using the file dialog to navigate to the new location.

Directivity Controls

Some additional controls, specific to the directional response mode, are positioned to the right of the directional response graph. These controls, and one indicator, are shown in Figure 8-9.

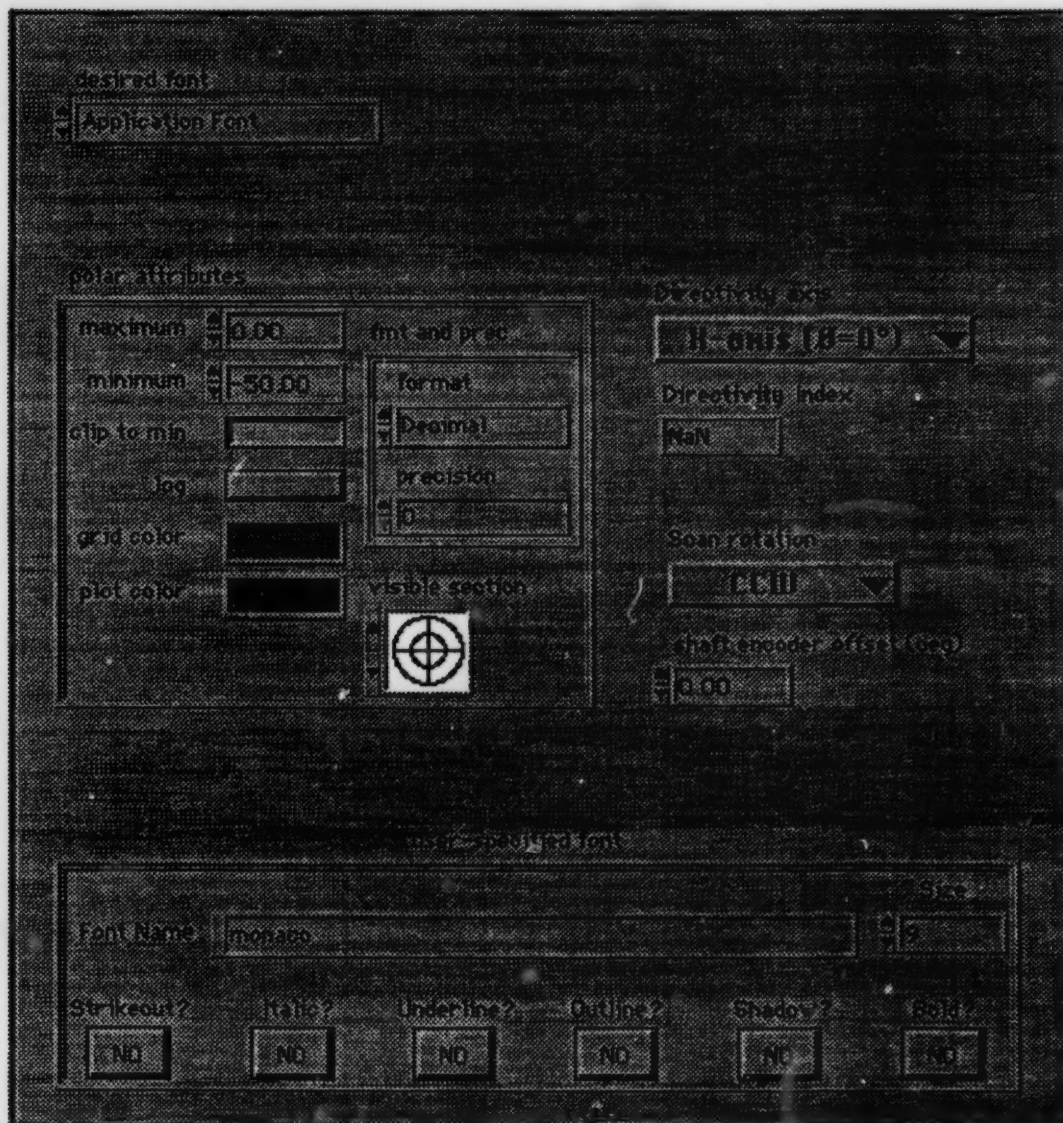


Figure 8-9 Directivity controls and indicators

desired font

This control selects the display font for the polar graph.

user-specified font

If the user-specified font is selected in the above control, these controls define the font attributes.

Directivity axis

A symmetry axis may be specified for calculating the directivity axis.



The positive X-axis ($\theta=90^\circ$, $\phi=0^\circ$) shall be the direction of zero azimuth and coincide with any existing horizontal acoustic axis (i.e. maximum response); ϕ is equal to the azimuth angle.



The positive Y-axis ($\theta=90^\circ$, $\phi=90^\circ$) shall be the direction of 90° azimuth and will be outward from the designated right-hand side of the transducer as viewed from the transducer.

Directivity Index

This indicator displays the calculated directivity index for the plot.

Scan rotation

This control selects the scan direction to match the station rotation controller panel setting.

shaft encoder offset (deg)

This control is used to enter the offset angle from the station zero-degree pulse position and the symmetry axis ($\phi=0$) position for the transducer.

Selecting the hydrophone calibration

You have the option of selecting alternate hydrophone calibration curves. During startup of the calibration procedure, a front panel (Figure 8-10) appears showing the calibration curve for the default standard hydrophone. Pressing *Done* confirms the default. This same panel can be accessed after startup by pressing the Std Hydrophone button from the DIRECTIONAL RESPONSE front panel.

To Select a different calibration data curve, press the *Select* button. Pressing the Select button opens another panel, shown in Figure 8-11. This standard LabVIEW file dialog is used to select a new hydrophone calibration file. Press *OK* to confirm the selection, or press *Cancel* to return without changing the current selection. If after having selected a new calibration curve, you then decide not to use it, pressing *Cancel* on the standard hydrophone selection front panel returns control to the receiving response front panel, and no changes are made to the standard current calibration data.

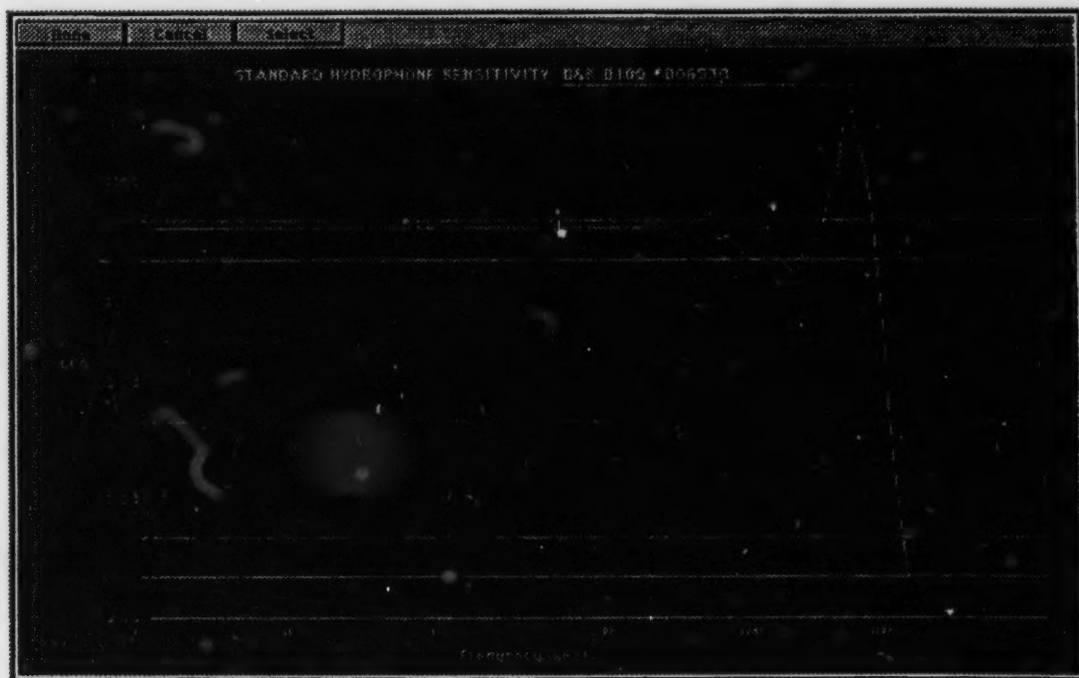


Figure 8-10 Hydrophone Sensitivity front panel

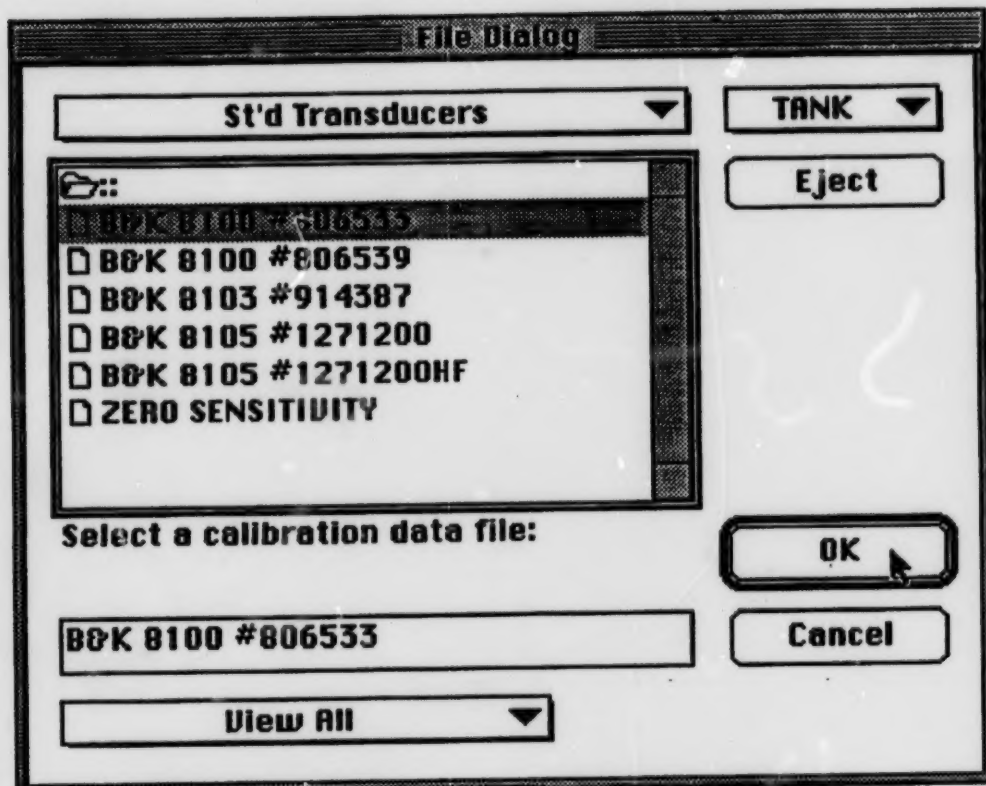


Figure 8-11 Selecting a new hydrophone

Selecting the calibration frequency range

The Setup Calibration Frequencies front panel (Figure 8-12) is used to modify the current frequency selections. The area on the left shows the current settings for the frequency range. Pressing the button below this area will return control to the calibration front panel, without changing the current settings.

New values are entered in the area to the right. Up to five frequencies may be specified. For each data point (0.1 degrees) one frequency is processed. The next frequency is processed on the next data point. Cycling through the frequencies continues until the scan is complete. Thus adding frequencies reduces the measurement resolution for any one frequency.

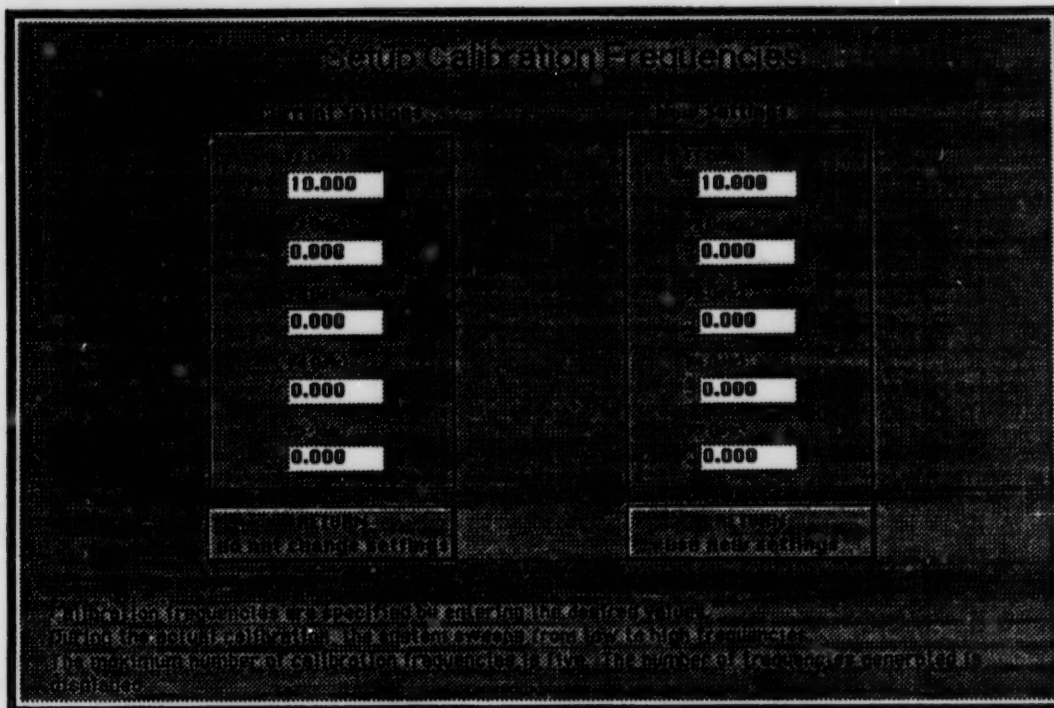


Figure 8-12 Setting the frequency range

Setting the projector drive levels

The *Setup Drive Levels* front panel (Figure 8-13) is used to establish the optimum signal voltage and hydrophone output preamplifier and filter gain setting. The settings made using this panel are communicated back to the calibration procedure front panel. Any or all of the graphs can be turned off using the *DISPLAY MODE CONTROLS*.

The *projector voltage (V_{rms})* and *projector current (I_{rms})* graphs plot the values over the current frequency range. The *projector voltage (V_{rms})* graph has an additional line shown in red. This is the maximum recommended projector voltage, which you enter using the *max projector volts* control. The red line provides an indication of projector overvoltages.

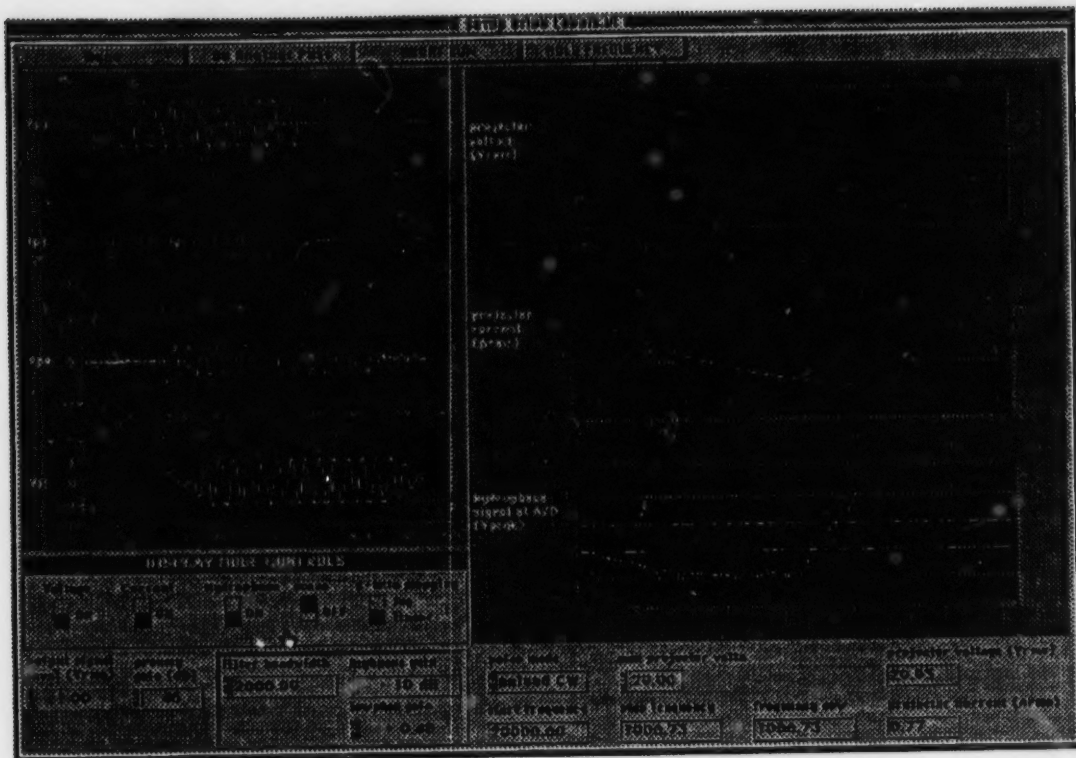


Figure 8-13 Setting the projector drive levels

Setup the pulse timing

The *Setup Pulse Specs* front panel (Figure 8-14) is used to set up the optimum pulse timing parameters for signal generation and data acquisition.

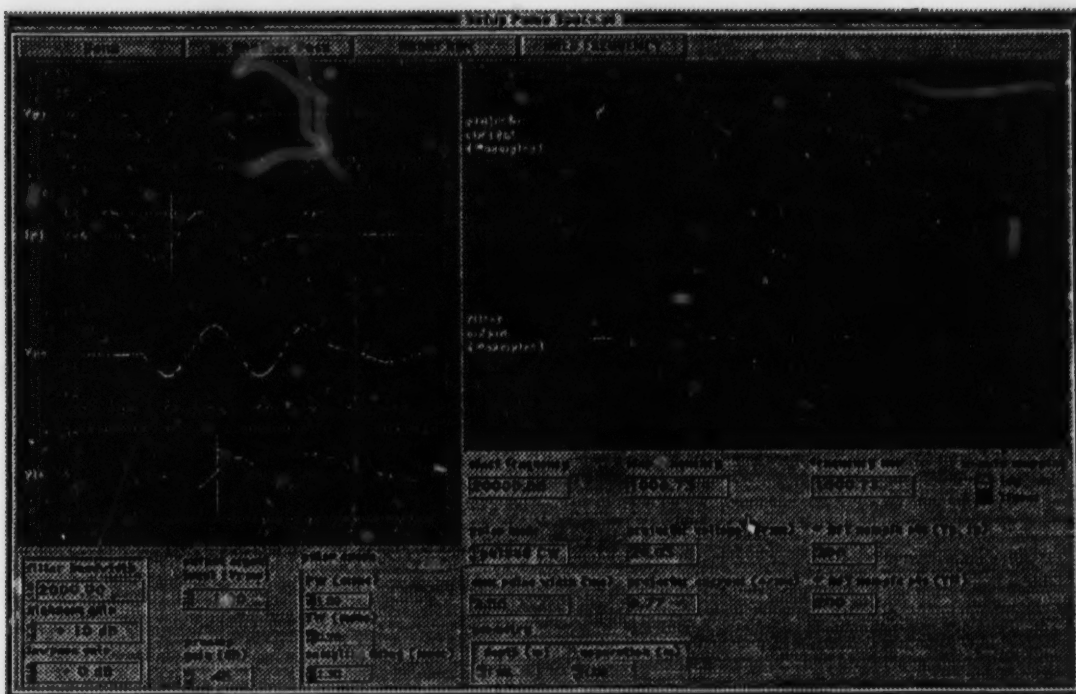


Figure 8-14 Setting the pulse specifications

The *projector current* (# samples) and *filter output* (# samples) graphs plot the number of sample points used to calculate the Discrete Fourier Transform (DFT) of the captured pulse waveform. The DFT is used to calculate the calibration data points. The graphs show the number of samples, calculated automatically by the program. Selecting a longer pulse width will result in a larger number of samples of hydrophone data. Typical values are between 100 and 300 samples, which provide a good compromise between processing speed and accuracy. The plots update at the end of each pass.

You change the pulse parameters using the *pulse specs* controls. The effect of changes to the parameters are seen in the graphs along the left side of the front panel, similar to the transmit response calibration front panel.

PW (msec) is the pulse width in milliseconds. This is the minimum width of the calibration source pulse out of the projector. An integral number of cycles will always be generated, and the entered value specifies a minimum pulse duration. The actual duration is typically longer, and will be the minimum time, greater than the specified value, to generate an integral number of cycles at the current frequency.

TW (msec) is the time window from which the acquired signal is sampled. The program will try to optimize the number of samples taken from within the window, and will always extract integral half-cycles.

The *sampling delay (msec)* control specifies how long the program waits, from the start of the excitation pulse, before the start of the time window, TW. The delay is necessary for the sound to propagate through the water from the projector to the hydrophone, and for the transients to dampen out in the hydrophone.

In addition to the sound pulse which propagates directly from the projector to the hydrophone, there will be reflected sound pulses from the surface of the water, and the sides and bottom of the tank. Typically, the surface reflection is the first and the worst reflection to arrive at the hydrophone. To limit the effects of interference and reverberations from these reflections, the excitation pulse is limited in duration. The *max pulse width (ms)* indicator provides a calculation of the expected arrival time of the surface reflection, based on the values you enter for depth and separation. You may still enter any value you wish for pulse width, the value is simply an indication of when to expect interference from a surface reflection. Limiting pulse duration to below this value will ensure the complete pulse arrives at the hydrophone before the wavefront of the surface reflection arrives.

Getting results

Pressing the *Results* button from the DIRECTIONAL RESPONSE front panel will cause the dialog shown in Figure 8-15 to appear. This gives you some flexibility in selecting which results you wish to generate. The available results are:

- plot the directional response polar graph on the attached LaserWriter printer,
- plot the directional response cartesian graph on the attached LaserWriter printer,
- save the calibration results to a data file for archiving or additional processing.

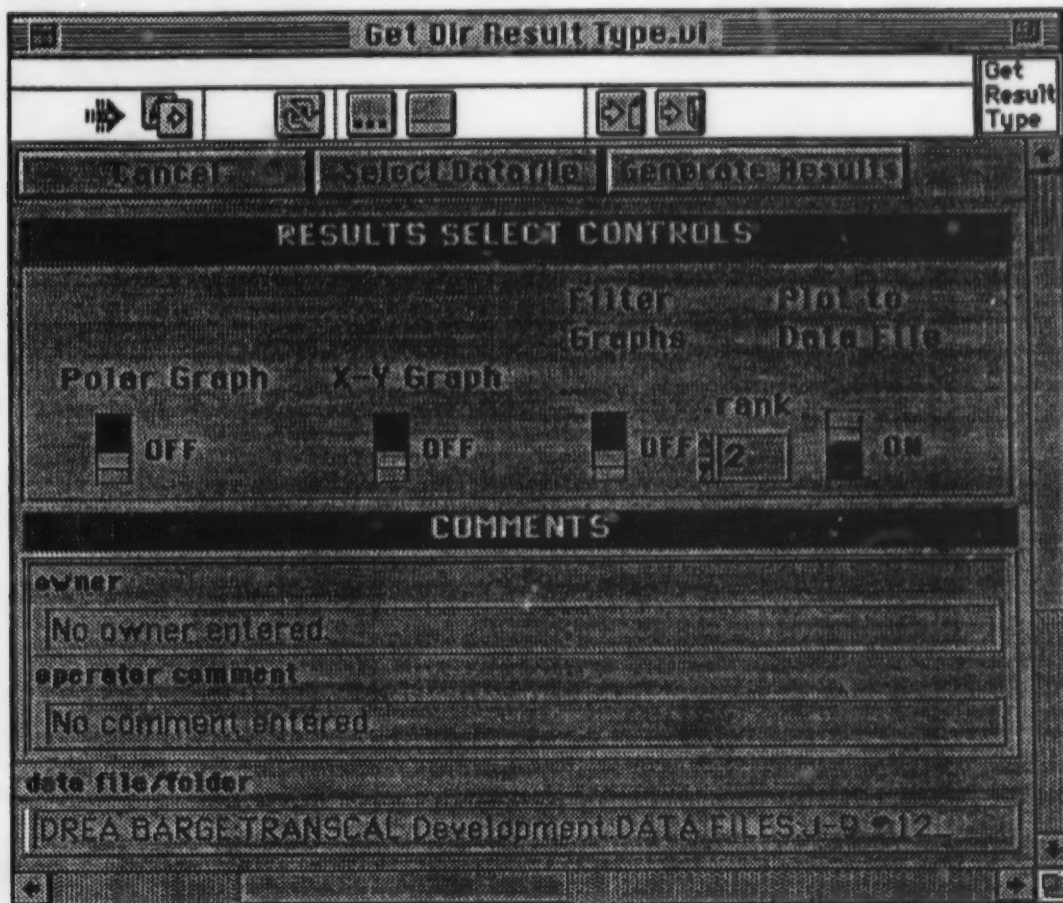


Figure 8-15 Results dialog

Use the *Polar Graph*, *X-Y Graph*, and *Plot to Data File* switches to select which results you want. By default, the data is always saved to a data file, to ensure the data does not inadvertently get lost. The data file is a tab-delimited spreadsheet text file, which can be read by most word processing, spreadsheet, or data processing programs. Sample results are given in Appendix A.

The *Filter Graphs* control allows you to filter out spurious data points, if any exist, on the printed results. The filter is a median filter, good for removing high frequency noise without corrupting valid transitions. The filter rank is selectable, and has a default value of 2, which is good for most noise spikes. Since filtering is rarely required, the default is not to filter the graphs.

Comments will appear on the printed plots, and will be saved in the data file. New comments are entered simply by typing in the fields provided. The *datafile/folder* indicator shows the current folder and filename prefix. To select a new folder, press the *Select Datafile* button at the top of the dialog panel. The actions to do this are the same as from the main panel, and are described in the following section.

When you have finished making your selection of desired results, press *Generate Results*. The data file will be created and the results will be saved to the file. The graphs will be printed in the background. There will be a short delay as the results are spooled to memory for background printing. The amount of time required for printing to complete will depend on the level of network activity, and can be several minutes. To check the progress of the printing, use the Print Monitor utility.

Setting the logging folder

The files created by TRANSCAL will be stored in the folder which you name. You select the storage folder using a standard LabVIEW dialog box. Unfortunately, due to LabVIEW evolving to cross-platform compatibility, "standard" LabVIEW is no longer "standard" Macintosh. The LabVIEW Macintosh compatibility has been compromised in this instance, in the interests of a greater cause. This point is mentioned because file selection can create some confusion for Macintosh users.

To select the file folder for logging, click on the select button next to the datafile/folder indicator shown in Figure 8-8, or the Select Datafile control in Figure 8-15. You will be presented with a dialog for file selection, seen in Figure 8-16.

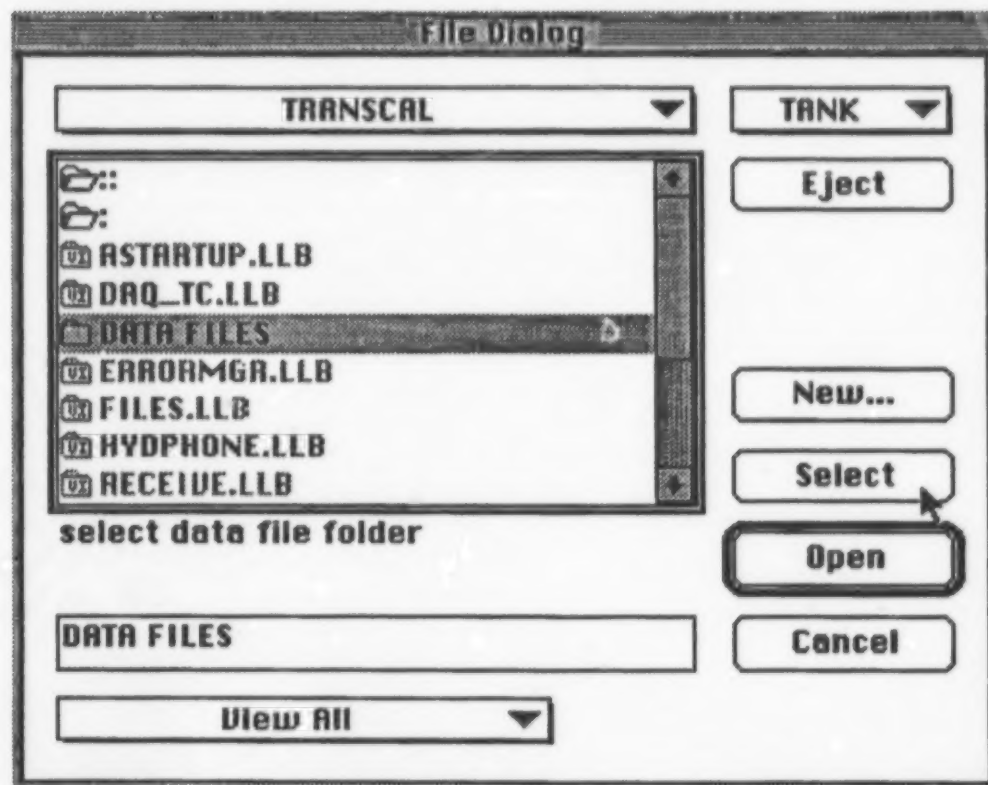


Figure 8-16 Select logging folder dialog

It is here where you have to forget you are using a Macintosh, and simply do as it says. You must select the folder and then click select as shown to choose the desired folder. If you "open" the folder, as you might be used to doing, you cannot then "select" the folder. You will be forced to "back up" one layer in the heirarchy and "select." The confusion arises the next time you access this dialog. As it should, the dialog opens to the currently selected folder. However, you cannot select from the currently selected folder; you must back up to the previous layer.

9 Using Reciprocity Mode

Starting Reciprocity using tone pulse or CW

You activate the receiving response calibration procedure from the *TRANSCAL* main panel. The front panel will startup as shown in Figure 9-1.

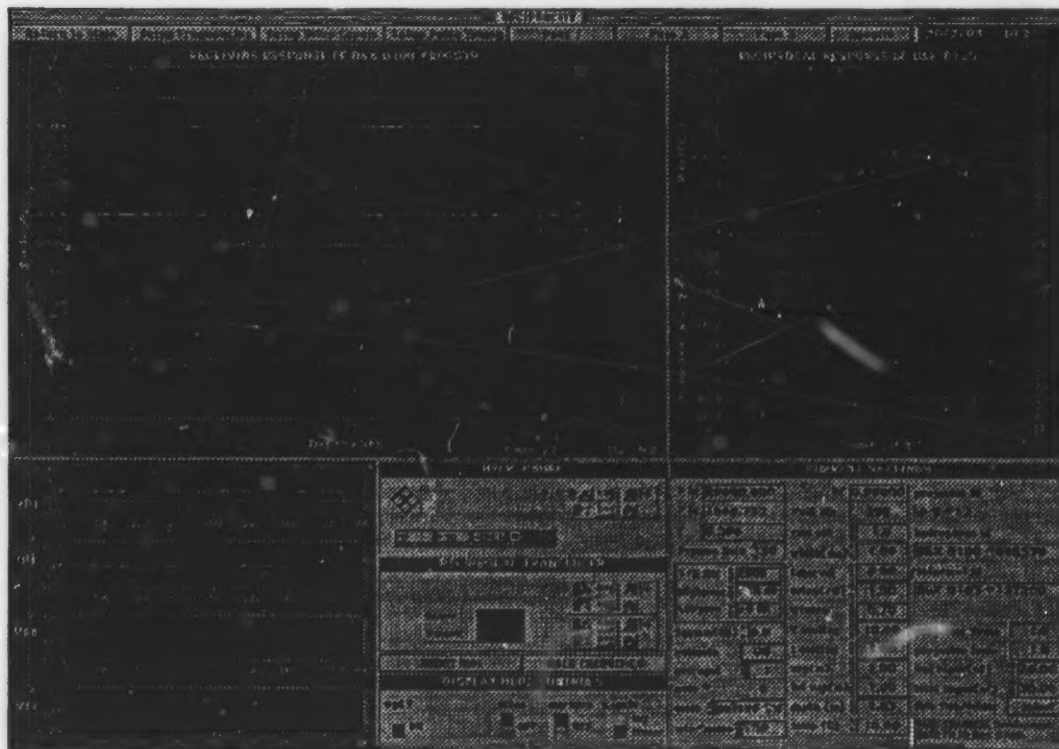


Figure 9-1 Reciprocity front panel

Reciprocity Calibration step-by-step

This section will present a simple guide to the basic operations of reciprocity calibration. All required parameters have default values, so it is possible to execute a calibration simply by pressing the *Pass 1*, *Pass 2*, and *Pass 3* buttons, and moving the transducers as required. Typically it will be necessary to change some values or settings for the actual experiment. The instructions below assume autogain will be used. If autogain is OFF, then you should setup the projector drive and signal gains as described in the sections later in the chapter.

Step 1: Startup

Startup as described above.

Step 2: Check the CURRENT SETTINGS

Check that the CURRENT SETTINGS are appropriate for your calibration experiment. The settings which may require changing are:

System Gains

Account for any system gain blocks not included in the preamp or filter gains. Typical examples would be the 6 dB preamp high-impedance gain or an attenuator added to cut down signal levels. Set this using the *System(dB)* control.

Number of Averages

If more than one pass is going to be averaged, set this using the *averages* control.

Excitation Mode

Usually, pulsed sine tones are used, but if CW is required, set it using the *mode* control.

Minimum scans

The program will calculate the correct number of scans, based on your pulse parameter selections. If you wish to look at a longer signal, set the minimum number of scans in the *min#scans* control.

Output Signal Level

The default output level is 1 volt rms. If this is too large, enter the required level using the *rms out* control.

Source Pulse Width

The minimum duration of the source pulse is set using the *width(ms)* control. The value entered will be a minimum length. The actual length will depend on the pulse frequency, partial cycles are not generated.

Pulse Repetition Interval

You can specify a delay from the end of one pulse to the beginning of the next. This is usually to allow more time for reverberations to die down. Setting this control is not usually required for a simple calibration, since by the time the calculations are complete and the graphs are updated, the reverberations have already disappeared. It is often used if there are system delays that have to be allowed for. Set the value using the *interval* control.

Sampling Delay

In water, there is a delay while the pulse travels from the projector to the hydrophone. The length of the delay, in milliseconds, is specified in the *delay(ms)* control so the system knows where to begin looking for received data.

Sampling Window

The *window* control is used to set the width, in milliseconds, of the time window from which the system will extract samples for calculations. If you wish to see the effects of changes to the pulse parameter settings, use the *Setup Pulse Timing* button.

Projector Scaling

The actual projector voltage is typically much larger than the available measurement range. The front panel of the projector voltage and current monitor has controls to select gain factors for voltage and current measurements. These scaling factors must be reported to TRANSCAL, using the *V scaling* and *I scaling* controls. If the selected gain is 100mV/V, for example, the scaling factor is 10.

Transducer Depth

Enter the actual depth in meters using the *depth (m)* control.

Temperature

Enter the water temperature in degrees Celsius using the *temp (C)* control.

Hydrophone Capacitance

The capacitance, in nanoFarads, of the test hydrophone is recorded using the *hyd capac(nF)* control. The total capacitance of the test hydrophone and cable is entered in the *total capac(nF)* control. These measurements are made by the operator, and are used only for recording in the data file.

Step 3 Check the frequency range

The current frequency settings are reported in the *F hi* and *F lo* indicators. If new settings are required, use the *Setup Frequencies* button to change the values, as described in a later section.

Step 4 Run the calibration

Three passes are required to complete the hydrophone calibration; one for the projector and hydrophone, one for the projector and reciprocal transducer, and one for the hydrophone and reciprocal transducer. These passes can be done in any order; the calibration curve will be completed when all passes have been completed.

Press *Pass 1* to begin the calibration run for the hydrophone and projector. While the calibration is underway, you can turn the graphs and markers on and off as desired. You can abort the run using the *ABORT RUN* button. To stop the program from advancing to the next frequency, press the *HOLD FREQUENCY* button.

When the run is completed, replace the hydrophone with the reciprocal transducer. Press *Pass 2* to begin the calibration run for the reciprocal transducer. Do not adjust the projector drive levels between Pass 1 and Pass 2. It is important to place the reciprocal transducer acoustic centre at the same location as was the hydrophone's acoustic centre.

When both transducers have been driven by the projector, replace the reciprocal transducer with the hydrophone, again being careful to position it correctly. Replace the projector with the reciprocal transducer. Set up the drive levels if necessary. Press Pass 3 to begin the calibration pass. While the passes are being run, the hydrophone sensitivity graph will display the hydrophone voltage signal received at the A/D convertor.

Step 5 Print the results

Use the Results button to get printed plots, or to save the calibration data to a file.

Controls and indicators

Modal Controls

The controls shown in Figure 9-2 redirect control to other front panels, or cease operation. This section briefly describes the function of the controls. The sections detailing the purpose and operation of the resulting front panels follows later in this chapter.

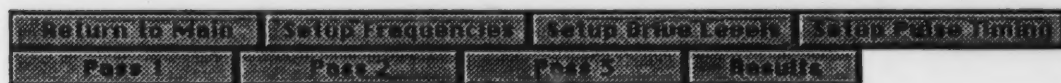


Figure 9-2 Modal controls

Return to Main

This button returns control to the TRANSCAL main panel, from which other calibration procedures can be accessed, or the session can be ended.

Setup Frequencies

This button is used to redirect control to the *Setup Frequencies* front panel, used to set the calibration frequency range.

Setup Drive Levels

This button is used to redirect control to the *Setup Drive Levels* front panel, used to set the projector drive levels.

Setup Pulse Timing

This button is used to redirect control to the *Setup Pulse Timing* front panel, used to set the pulse generation and sampling parameters.

Pass 1

This button starts the data acquisition process for the hydrophone driven by the projector.

Pass 2

This button starts the data acquisition process for the reciprocal transducer driven by the projector.

Pass 3

This button starts the data acquisition process for the hydrophone driven by the reciprocal transducer.

Results

This button is used to plot calibration curves or save the calibration data to a file.

Receiving Response graph

The *Receiving Response* graph (Figure 9-3) displays the Receiving Response, also referred to as the hydrophone sensitivity graph. Hydrophone sensitivity is displayed, as a function of frequency, as a voltage in units of decibels relative to one volt per microPascal of sound pressure at a distance of one metre. You can change the X and Y scale minimum and maximum values by typing into the fields directly, or by editing the values using the standard LabVIEW graph editing pop-up menus. When the graphs are plotted, the current values are transferred to the plotted output. That is, what-you-see-is-what-you-get.



Figure 9-3 Receiving Response graph

Hydrophone graph controls

The hydrophone sensitivity graph controls are shown in Figure 9-4. Final results appear only in the form of a hydrophone sensitivity graph. Therefore, there are no alternate selection options for the graph type control.



Figure 9-4 Hydrophone sensitivity graph controls

The other controls shown are standard LabVIEW graph controls. The graph cursor control moves the cursor within the graph area. Typically, the cursor is locked to the plot. The cursor coordinates (Frequency and Sensitivity) are updated in the bottom right corner of the plot area.

Reciprocal Transducer graph

The graphs on the right side of the screen (Figure 9-5) display the transducer receive sensitivity and transmit current response. As for the hydrophone response graph, you can change the X and Y scale axes for display and plotting.

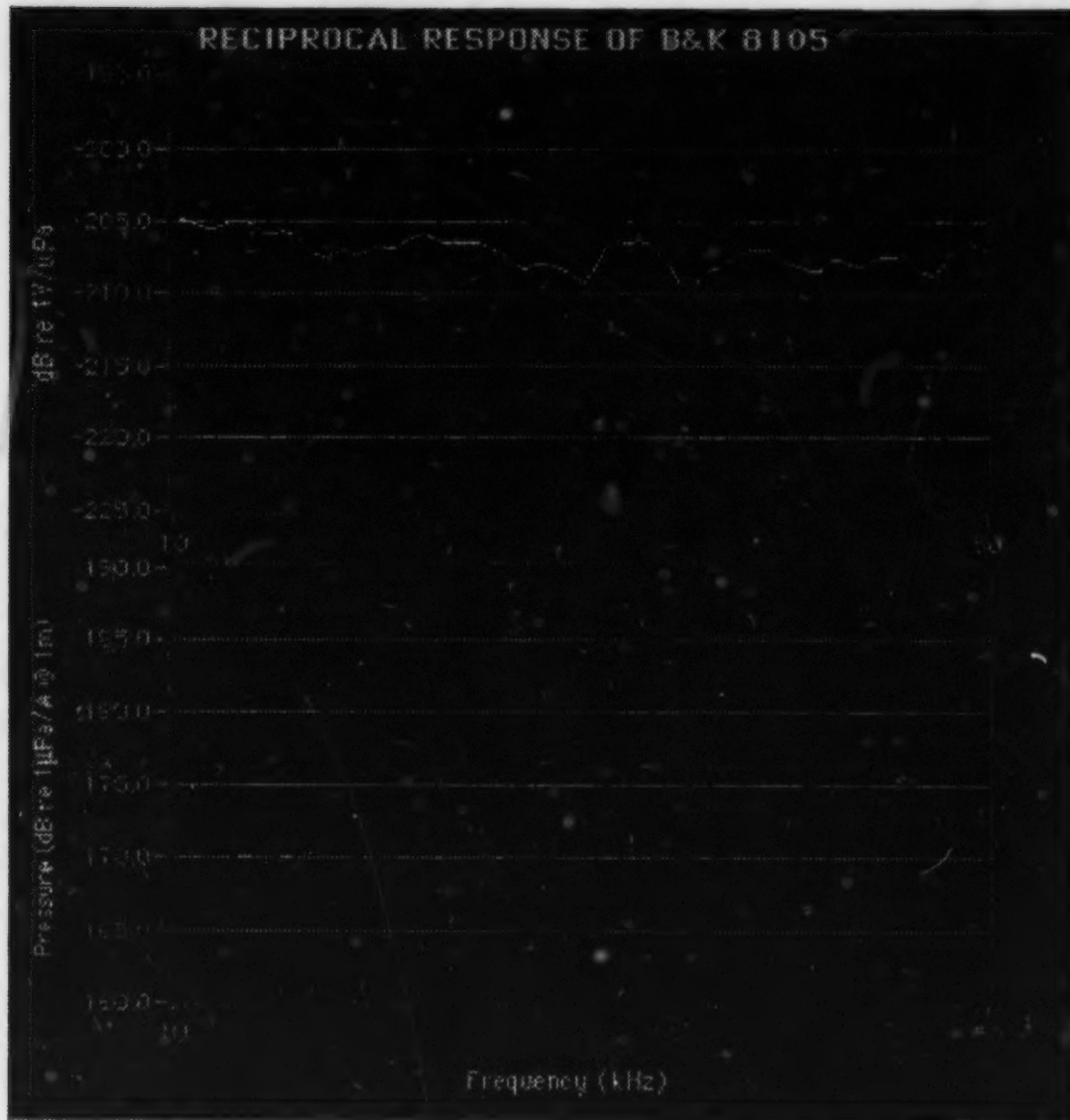


Figure 9-5 Reciprocal Response graph

Reciprocal Transducer graph controls

The reciprocal transducer graph control are similar to the hydrophone graph controls and are shown in Figure 9-6.

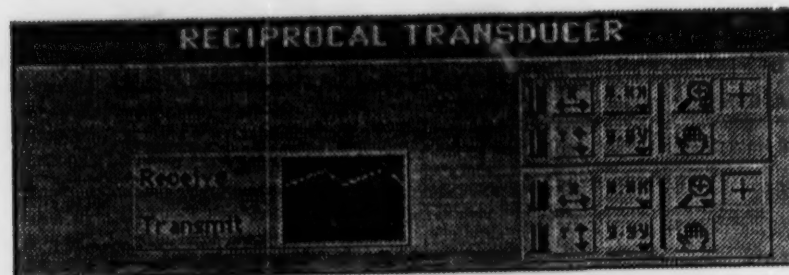


Figure 9-6 Reciprocal transducer graph controls

Acquired data graphs

During a calibration run, data are sampled from the projector voltage and current and hydrophone voltage signals. The sampled data can be viewed in real time in the data scan graphs, shown in Figure 9-7. As for all the graphs, both X and Y axes can be set to autoscale, or axes values can be fixed to values which you enter. The displayed data are projector voltage (V_{pj}); projector current (I_{pj}); preamp output voltage (V_{pa}); and filter output (V_{fl}).

The I_{pj} and V_{fl} graphs include markers which indicate the beginning and end of the data samples used to calculate the transducer calibration curves. This feature is very helpful in determining the optimum values for pulse sampling.

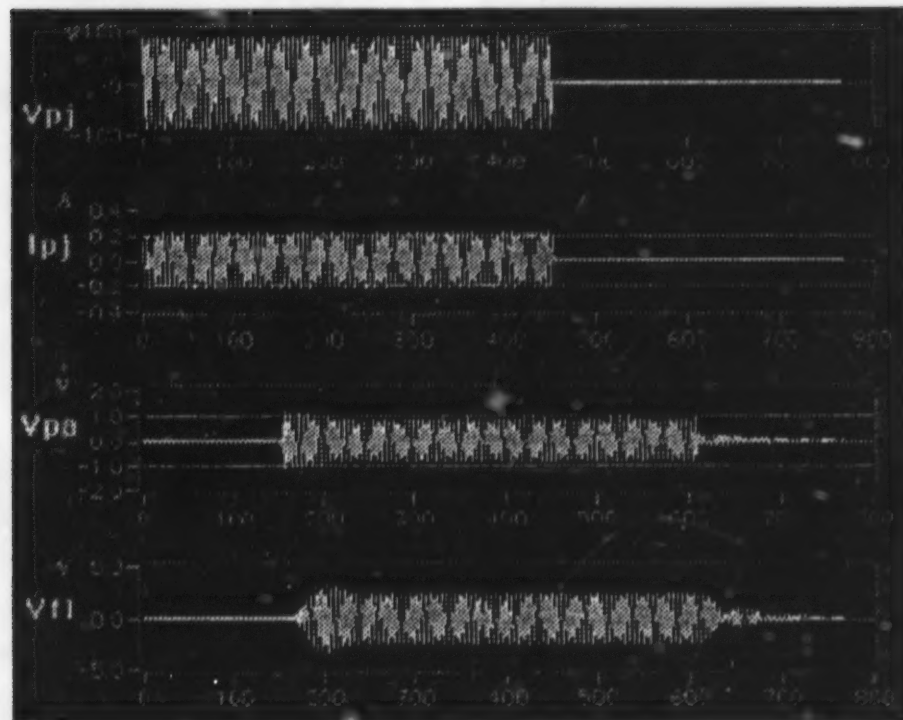


Figure 9-7 Sampled data graphs

Display Mode Controls

The controls in Figure 9-8 are used to select which graphs are updated during a calibration run. Often, you will want to turn off some of the graphs to speed up the data acquisition. In the receiving response mode, hydrophone voltage is displayed during a run. Hydrophone sensitivity is calculated at the end of every pass through the calibration frequency range. Typically, the hydrophone voltage graph is left on, and the others are turned off. This is the default configuration. Also, there is a control to change the X-axis display mode between log and linear.

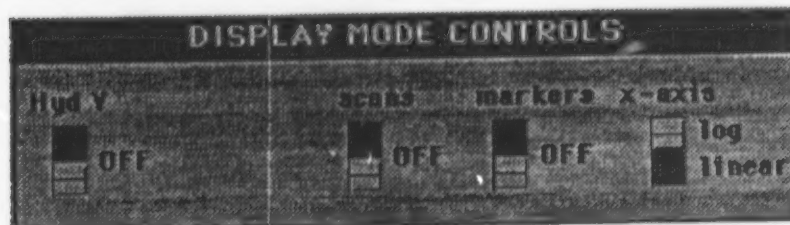


Figure 9-8 Display Mode Controls

Calibration run controls

The calibration run controls (Figure 9-9) are used to pause or abort the calibration process. The *HOLD FREQUENCY* button causes the program to cycle or loop at the current frequency. While the program is looping, all normally active controls remain active, and new data is acquired. Typically, this feature is used to view or modify the calibration results at a point of interest. The *ABORT RUN* button stops the current scan, in effect returning to the beginning.

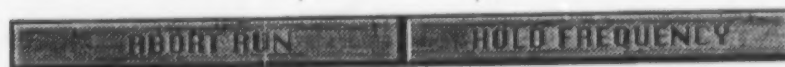


Figure 9-9 Calibration run controls

Current Settings

Current Settings, shown in Figure 9-10, is a collection of controls and indicators which provide an interactive reporting of the current process status.

CURRENT SETTINGS			
F _{hi}	50000.000	DF	0.98000
F _{lo}	10135.145	seal pts	80
F	10135.145	rms out	1.0
Preampl Gain	49	width(ms)	1.80
1/2 BW	2000	interval	0.00
Highpass	+10 dB	delay(ms)	1.50
Lowpass	+0 dB	window	0.70
System(dB)	6.0	Y scaling	100.00
autogain	ON	I scaling	1.00
averages	1	sep(m)	1.00
pass	0	tot sep(m)	1.00
mode	pulsed CW	depth (m)	1.83
min*secs	750	temp (C)	10.00
		projector id	J-9 #12
		hydrophone id	B&K 8100 #806539
		reciprocal id	B&K 8105 #1271200
		projector Yrms	63.4
		projector Irms	0.0
		hyd capac(nF)	36.00
		total capac(nF)	36.00
		data file/folder	select
TANK-TRANSCAL Development DATA FILES-B&K 8100 #806539			

Figure 9-10 Current Settings controls and Indicators

F_{hi}

This indicator shows the maximum frequency setting for the calibration run.

F_{lo}

This indicator shows the minimum frequency setting for the calibration run.

F

This indicator shows the current frequency setting during the calibration run.

Preamplifier Gain

When autogain is turned on, this control shows the current gain setting for the RTS 3510B programmable amplifier. When autogain is turned off, the control is used to enter the gain setting to be used for the calibration.

1/2 BW

This control determines the bandpass of the brickwall filter. You enter the filter half-bandwidth, which is the frequency separation between the current centre frequency and the lowpass and highpass cutoff frequencies. That is, the total bandwidth is twice the entered value.

Highpass

This indicator shows the current highpass gain setting for the brickwall filter. If autogain is on, the value is updated automatically. If autogain is off, you select the desired value from the available settings for the filter.

Lowpass

This indicator shows the current lowpass gain setting for the brickwall filter. If autogain is on, the value is updated automatically. If autogain is off, you select the desired value from the available settings for the filter.

System (dB)

This control is used to enter any other gain blocks which are present in the system. For example, if an attenuator is required, its gain value would be entered here.

◆ **Note** The system gain control is configured to default to 6 dB (to account for the RTS 3510B gain offset when output into a high-impedance load). ◆

autogain

This control is used to turn autogain on or off. When autogain is on, the system tries to maintain an optimum voltage level at the analog-to-digital convertor input. It does this by adjusting the values for the preamp and filter gain stages.

averages

This control is used to enter the number of passes which get averaged to calculate the final calibration curve.

pass #

This indicator shows the current pass number, providing feedback on the progress of the calibration.

mode

This control is used to select the signal source mode, that is pulsed sine or continuous waveform (CW). The mode can be changed at any time, even during a calibration pass.

min # scans

During data acquisition, the system calculates the number of minimum number of scans required to capture the specified pulse. This is the data which is displayed in the acquired data graphs. Sometimes, you may want to acquire additional data, say to look at reverberation effects. This control is used to set the minimum number of scans acquired. The actual duration of acquired data gets displayed as the X-axis of the graphs, and will depend on the current sampling frequency. For example, 750 scans at a 250 kHz sampling rate would result in 3 milliseconds of data.

DF

This is the decrementing factor used to calculate the frequency points for the calibration data, where $f(n+1) = DF * f(n)$.

cal pts

This indicator shows the number of calibration points in the current calibration. Increasing the decrementing factor raises the number of points, up to a maximum of 1024.

rms out

This control is used to enter the source signal output level. The control is set to limit the maximum output level to 1.0 volts rms, a standard value for amplifier calibration.

width (ms)

This control sets the source signal pulse width for pulsed operation. The value, in milliseconds, represents a minimum pulse width. An integral number of waveform cycles will always be generated, so the actual pulse width is typically longer than the specified value.

interval

This control is used to specify a minimum interval, in milliseconds, between the end of one excitation pulse and the beginning of the next. Under normal circumstances, the next pulse is generated once the calculations have been completed for the previous pulse. If the value of the control is less than the calculation time, the control will have no noticeable effect.

delay (ms)

This control is used to enter the delay from the start of the excitation pulse to the beginning of sampling of the hydrophone voltage. Typically, it would be set to the travel time for the pulse from the projector to the hydrophone, plus some time to allow the initial transients to decay.

window

This control is used to enter the allowable time window, in milliseconds, for sampling the hydrophone voltage waveform. The program will attempt to maximize the amount of data acquired to improve the result. A maximum number of integral half-cycles will be sampled from within the specified window. The time window begins at the end of the specified delay, and continues for the value specified in this control.

V scaling

This control is used to enter the voltage scaling factor manually selected on the front panel of the VIT-13 amplifier voltage and current monitor. For example, if the voltage setting is 100mV/V, then the scaling factor is 10.

I scaling

This control is used to enter the current scaling factor manually selected on the front panel of the VIT-13 amplifier voltage and current monitor. For example, if the current setting is 1 V/A, then the scaling factor is 1.

std sep(m)

This control is used to enter the separation, in meters, between the projector and the hydrophone.

depth (m)

This control is used to enter the depth, in meters, between the surface and the hydrophone.

temp (C)

This control is used to enter the water temperature, in degrees Celsius. This value is used to annotate the data plots, and is stored to file with the calibration data.

projector id

This control is used to enter the identifier string for the projector.

hydrophone id

This control is used to enter the identifier string for the standard hydrophone. The identifier is saved in the stored data files.

reciprocal id

This control is used to enter the identifier string for the reciprocal transducer. The identifier is saved in the stored data files, used to form the graph titles, and becomes the data file prefix.

sensitivity (dB)

This indicator shows the standard hydrophone sensitivity at the current test frequency.

projector Vrms

This indicator shows the applied projector voltage, in rms volts, at the current frequency.

projector Irms

This indicator shows the applied projector current, in rms amperes, at the current frequency.

hyd capac (nF)

This control is used to enter the measured capacitance, in nanoFarads, of the unknown hydrophone. This value is stored in the data file.

total capac (nF)

This control is used to enter the measured capacitance, in nanoFarads, of the unknown hydrophone and the test cable.

data file/folder

This indicator shows the current folder and filename to which saved data will be stored. The filename prefix forms the root of the filename. A date and time tag is appended to this prefix to create a unique filename for each file. You change the folder and filename by pressing the select button and using the file dialog to navigate to the new location.

Selecting the calibration frequency range

The Setup Calibration Frequencies front panel (Figure 9-11) is used to modify the current frequency range and resolution. The area on the left shows the current settings for the frequency range. Pressing the button below this area will return control to the calibration front panel, without changing the current settings.

New values are entered in the area to the right. The frequency decrement (DF) value determines the resolution of the calibration frequencies. The closer the value is to the maximum of 1.0, the closer the next frequency value will be to the previous one, that is a higher or finer resolution. Decreasing the value will result in a larger difference, or coarser resolution. There are a maximum of 1024 data points possible. The value for DF which would result in 1024 data points being created is called *DFMAX*. Creating the maximum number of data points is easy — just press the *USE DFMAX* button. The # *cal* frequencies indicator provides instant feedback on how many sample points would result from your current settings. Typically, lower numbers are used to scan through the range quickly to get a first look at the calibration curve, set drive levels, etc. Later, higher numbers of points are used to increase the resolution of the final calibration.

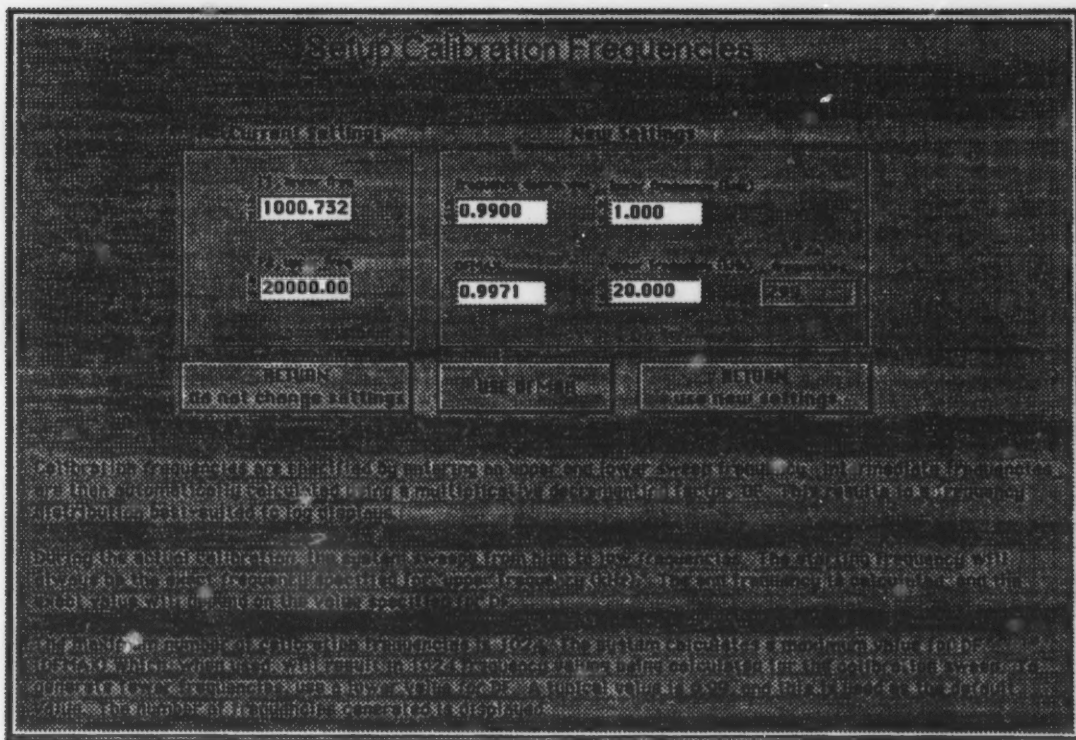


Figure 9-11 Setting the frequency range

Setting the projector drive levels

The *Setup Drive Levels* front panel (Figure 9-12) is used to establish the optimum signal voltage and hydrophone output preamplifier and filter gain setting. This feature is typically used if the system is going to be used with autogain off. The settings made using this panel are communicated back to the calibration procedure front panel. Any or all of the graphs can be turned off using the *DISPLAY MODE CONTROLS*.

The *projector voltage (Vrms)* and *projector current (Irms)* graphs plot the values over the current frequency range. The *projector voltage (Vrms)* graph has an additional line shown in red. This is the maximum recommended projector voltage, which you enter using the *max projector volts* control. The red line provides an indication of projector overvoltages.

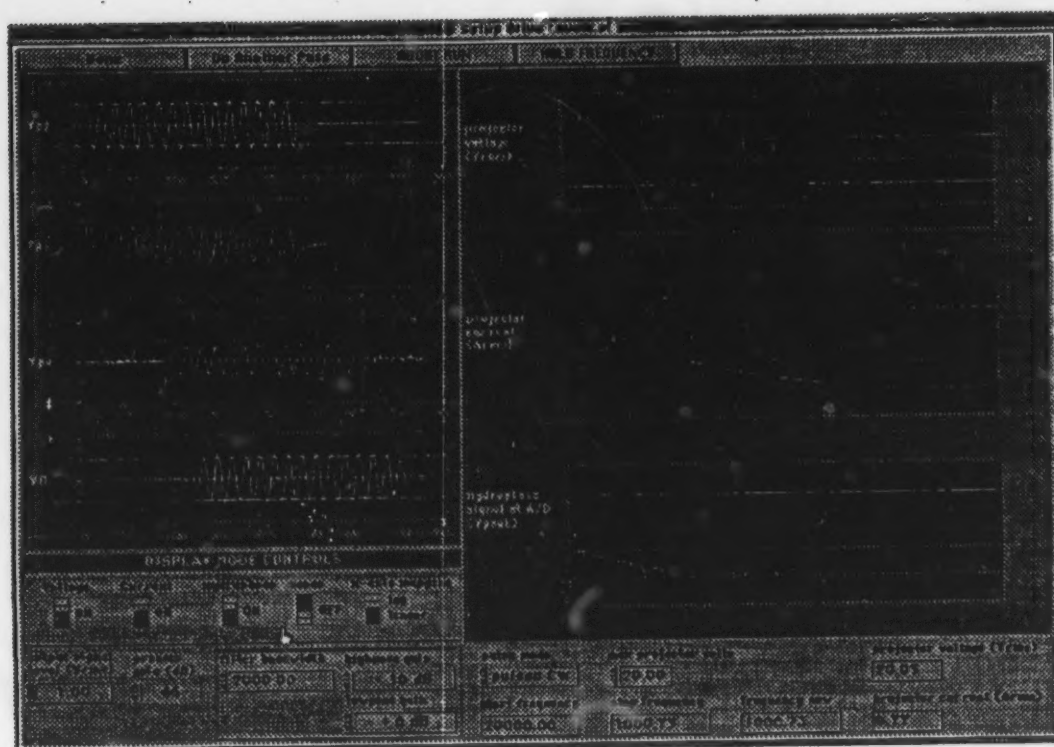


Figure 9-12 Setting the projector drive levels

Setup the pulse timing

The *Setup Pulse Specs* front panel (Figure 9-13) is used to setup the optimum pulse timing parameters for signal generation and data acquisition.

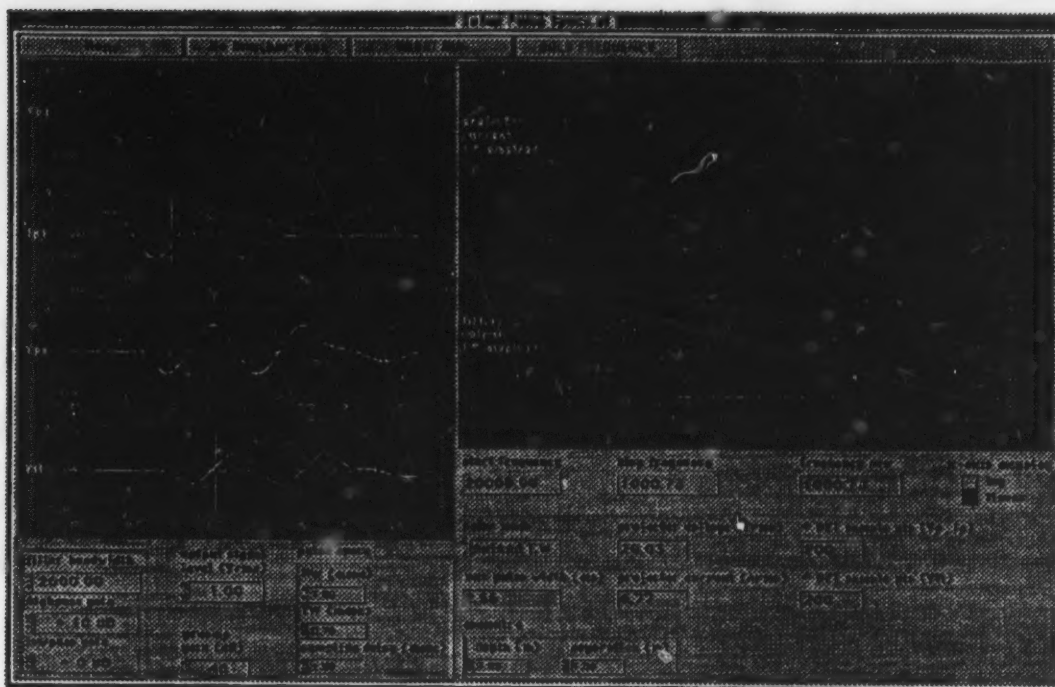


Figure 9-13 Setting the pulse specifications

The *projector current (# samples)* and *filter output (# samples)* graphs plot the number of sample points used to calculate the Discrete Fourier Transform (DFT) of the captured pulse waveform. The DFT is used to calculate the calibration data points. The graphs show the number of samples, calculated automatically by the program. Selecting a longer pulse width will result in a larger number of samples of hydrophone data. Typical values are between 100 and 300 samples, which provide a good compromise between processing speed and accuracy. The plots update at the end of each pass.

You change the pulse parameters using the *pulse specs* controls. The effect of changes to the parameters are seen in the graphs along the left side of the front panel, similar to the transmit response calibration front panel.

PW (msec) is the pulse width in milliseconds. This is the minimum width of the calibration source pulse out of the projector. An integral number of cycles will always be generated, and the entered value specifies a minimum pulse duration. The actual duration is typically longer, and will be the minimum time, greater than the specified value, to generate an integral number of cycles at the current frequency.

TW (msec) is the time window from which the acquired signal is sampled. The program will try to optimize the number of samples taken from within the window, and will always extract integral half-cycles.

The *sampling delay (msec)* control specifies how long the program waits, from the start of the excitation pulse, before the start of the time window, *TW*. The delay is necessary for the sound to propagate through the water from the projector to the hydrophone, and for the transients to dampen out in the hydrophone.

In addition to the sound pulse which propagates directly from the projector to the hydrophone, there will be reflected sound pulses from the surface of the water, and the sides and bottom of the tank. Typically, the surface reflection is the first and the worst reflection to arrive at the hydrophone. To limit the effects of interference and reverberations from these reflections, the excitation pulse is limited in duration. The *max pulse width (ms)* indicator provides a calculation of the expected arrival time of the surface reflection, based on the values you enter for depth and separation. You may still enter any value you wish for pulse width, the value is simply an indication of when to expect interference from a surface reflection. Limiting pulse duration to below this value will ensure the complete pulse arrives at the hydrophone before the wavefront of the surface reflection arrives.

Getting results

Pressing the *Results* button from the RECIPROCITY front panel will cause the dialog shown in Figure 9-14 to appear. This gives you some flexibility in selecting which results you wish to generate. The available results are:

- plot the hydrophone sensitivity graph on the attached LaserWriter printer, and
- save the calibration results to a data file for archiving or additional processing.

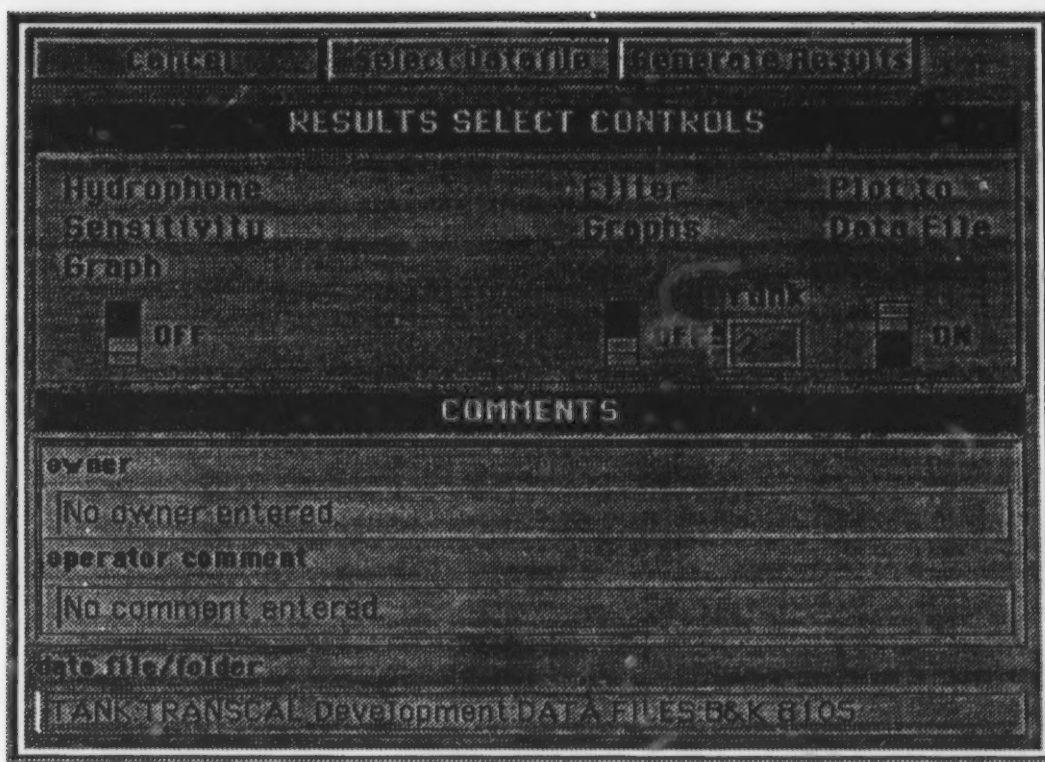


Figure 9-14 Results dialog

Use the *Hydrophone Sensitivity Graph*, and *Plot to Data File* switches to select which results you want. By default, the data is always saved to a data file, to ensure the data does not inadvertently get lost. The data file is a tab-delimited spreadsheet text file, which can be read by most word processing, spreadsheet, or data processing programs. Sample results are given in Appendix A.

The *Filter Graphs* control allows you to filter out spurious data points, if any exist, on the printed results. The filter is a median filter, good for removing high frequency noise without corrupting valid transitions. The filter rank is selectable, and has a default value of 2, which is good for most noise spikes. Since filtering is rarely required, the default is not to filter the graphs.

Comments will appear on the printed plots, and will be saved in the data file. New comments are entered simply by typing in the fields provided. The *datafile/folder* indicator shows the current folder and filename prefix. To select a new folder, press the *Select Datafile* button at the top of the dialog panel. The actions to do this are the same as from the main panel, and are described in the following section.

When you have finished making your selection of desired results, press *Generate Results*. The data file will be created and the results will be saved to the file. The graphs will be printed in the background. There will be a short delay as the results are spooled to memory for background printing. The amount of time required for printing to complete will depend on the level of network activity, and can be several minutes. To check the progress of the printing, use the Print Monitor utility.

Setting the logging folder

The files created by TRANSCAL will be stored in the folder which you name. You select the storage folder using a standard LabVIEW dialog box. Unfortunately, due to LabVIEW evolving to cross-platform compatibility, "standard" LabVIEW is no longer "standard" Macintosh. The LabVIEW Macintosh compatibility has been compromised in this instance, in the interests of a greater cause. This point is mentioned because file selection can create some confusion for Macintosh users.

To select the file folder for logging, click on the select button next to the datafile/folder Indicator shown in Figure 9-10, or the Select Datafile control in Figure 9-14. You will be presented with a dialog for file selection, seen in Figure 9-15.

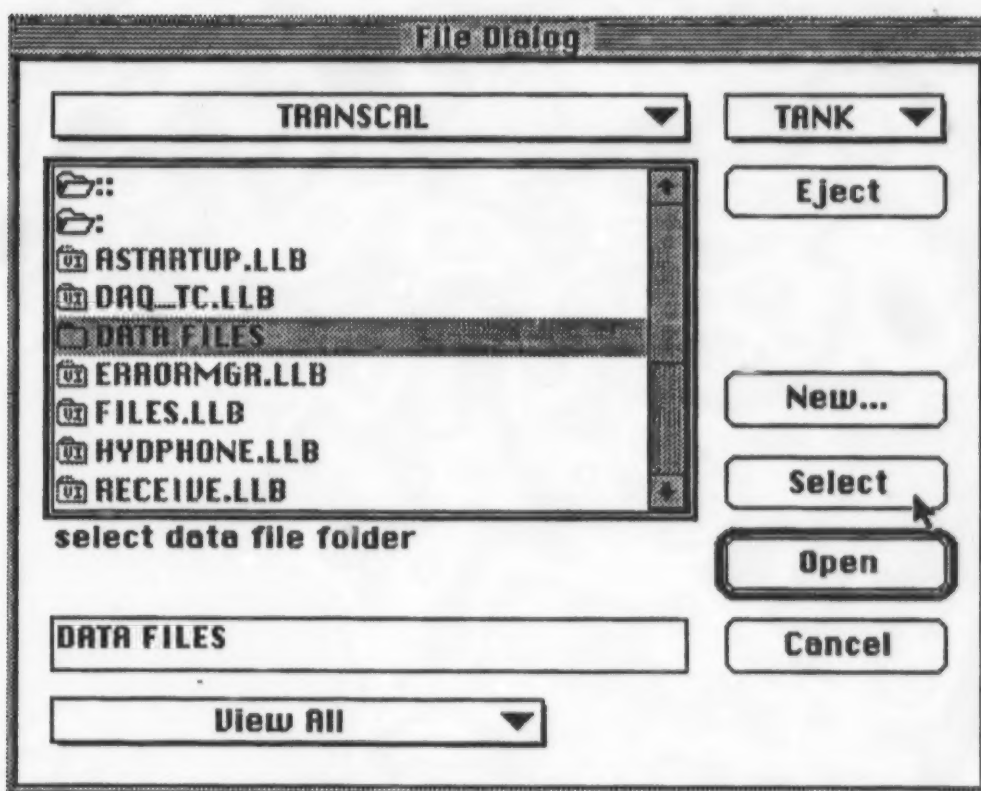


Figure 9-15 Select logging folder dialog

It is here where you have to forget you are using a Macintosh, and simply do as it says. You must select the folder and then click select as shown to choose the desired folder. If you "open" the folder, as you might be used to doing, you cannot then "select" the folder. You will be forced to "back up" one layer in the heirarchy and "select." The confusion arises the next time you access this dialog. As it should, the dialog opens to the currently selected folder. However, you cannot select from the currently selected folder; you must back up to the previous layer.

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The report is a part of a two volume set. It describes the work done in a research contract to develop transducer calibration software, referred to as TRANSCAL, for use in the Defence Research Establishment Atlantic (DREA) calibration facilities. This volume describes the procedures for directional response measurements and reciprocity measurements. The first volume (CR/97/414) contains a description of the procedures for the transmitting voltage response and receiving response using swept sine, pulse or CW. The TRANSCAL software controls the calibration procedure, acquires and processes the received data, and presents the results. The system has been developed using the LabVIEW programming environment, to operate on a Macintosh Quadra 900.

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